Landslides of OREGON: North Coast

5 SEA GRANT

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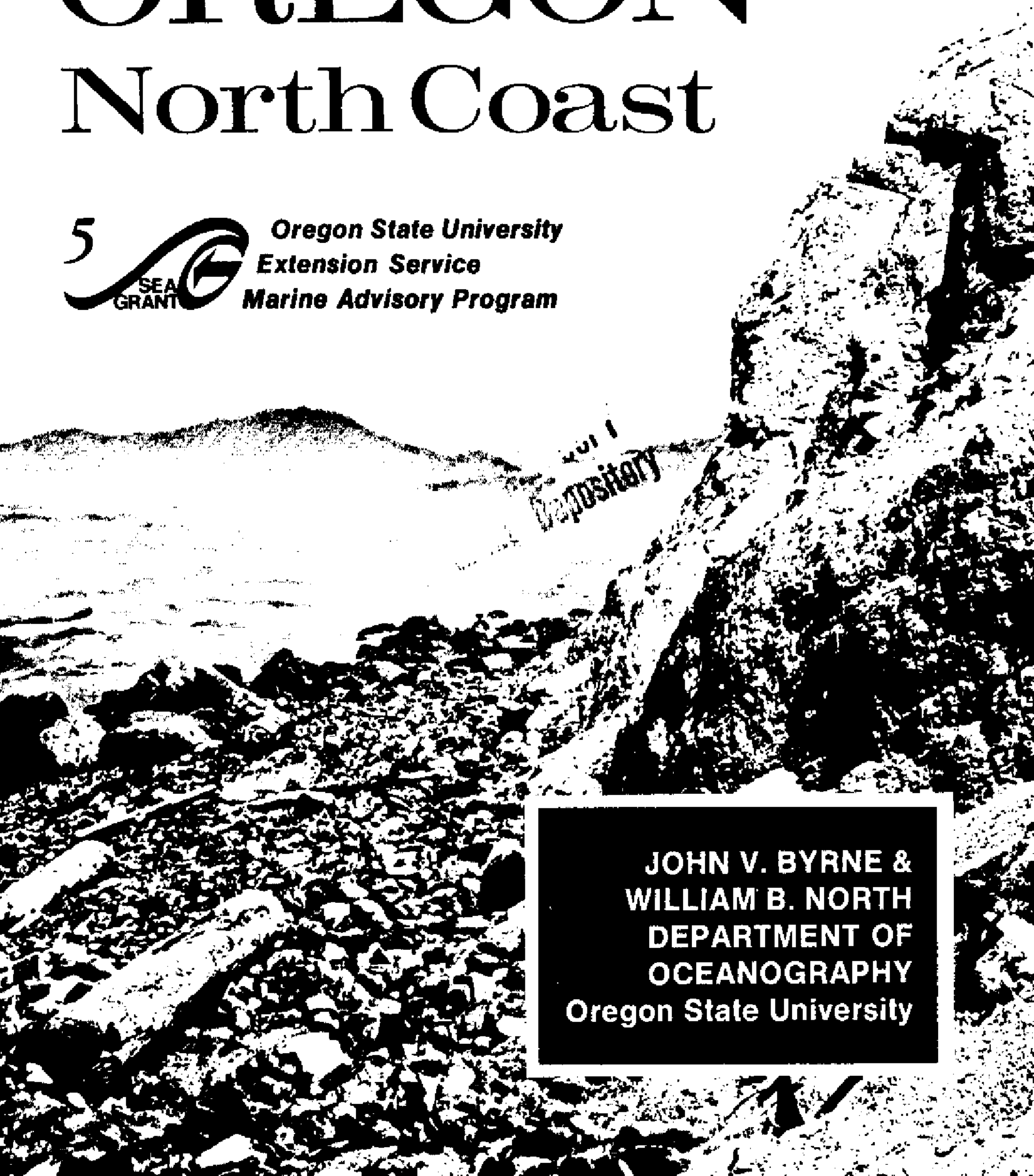

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OCEANOGRAPHY
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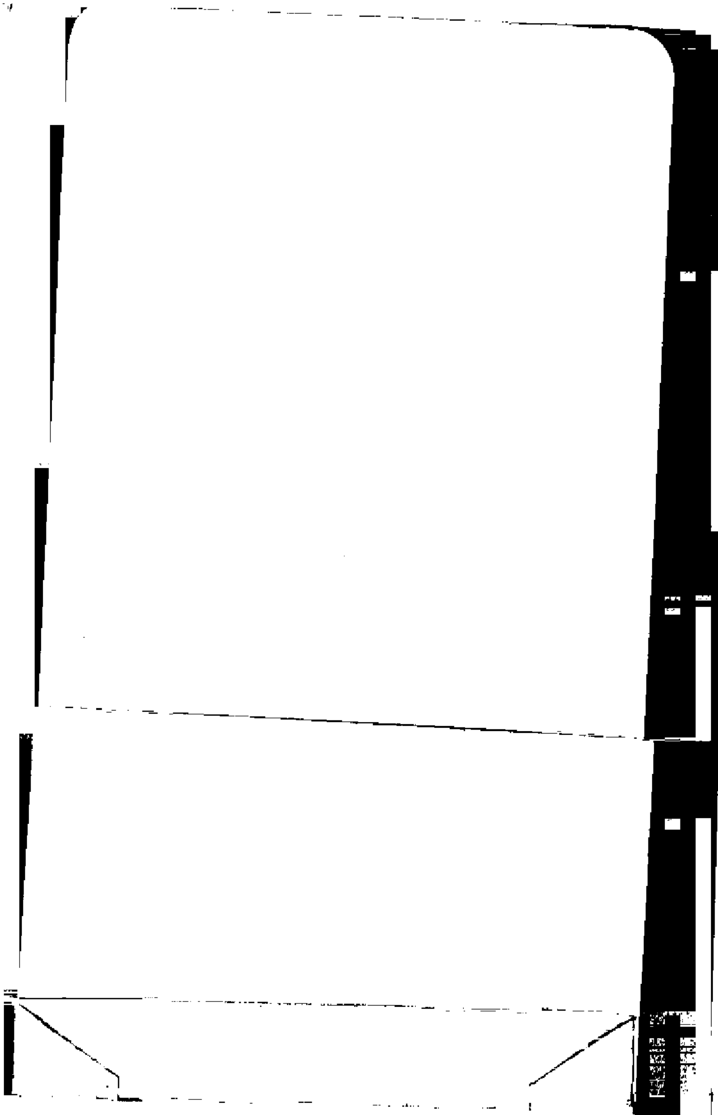


Introduction

Increased development of the Oregon coast for domestic housing, recreation, and industry makes it economically important to understand processes of coastal erosion and deposition. Of all the erosional processes, landsliding is undoubtedly the most important. Landslides occur along 70 of the 150 miles of northern Oregon coast from the Columbia River to Florence.

Coastal Landforms and General Geology

The northern Oregon coast, from the Columbia River to a point six miles north of the Siuslaw River, includes a wide variety of shoreline features. Short, narrow beaches lie at the base of low cliffs which form the seaward edge of uplifted marine terraces or benches. Numerous headlands, estuaries, and bays interrupt the continuity of the terraces and beaches. Where the coastline is low, near the bays, active sand dunes are present. Stabilized dunes are evident in some of the low areas and on some of the terraces.

Rocks exposed to erosion along the Oregon Coast are mainly sedimentary rocks of Tertiary age (2 to 60 million years old). The rocks are mostly sandstones, siltstones, mudstones, and shales.

Unconsolidated sediments of Pleistocene age (20,000 to 2 million years old) are exposed in the terraces along the coast. These sediments are mainly sands and silts, with layers of gravel, coarse sand, fossil wood, peat, and in some places, thin beds of sandy clay. These sediments overlie the older Tertiary rocks in many places. Although they are often unreported on geologic maps, these unconsolidated sediments are extremely important in local landslides, and must be included when the total material involved in the slide is considered.

The headlands, which constitute the most resistant features along the coast, are with one exception (Cape Kiwanda) composed of igneous* rock, primarily basalts and other volcanic types of rock.

** Rocks which have formed by cooling of a molten mass.*

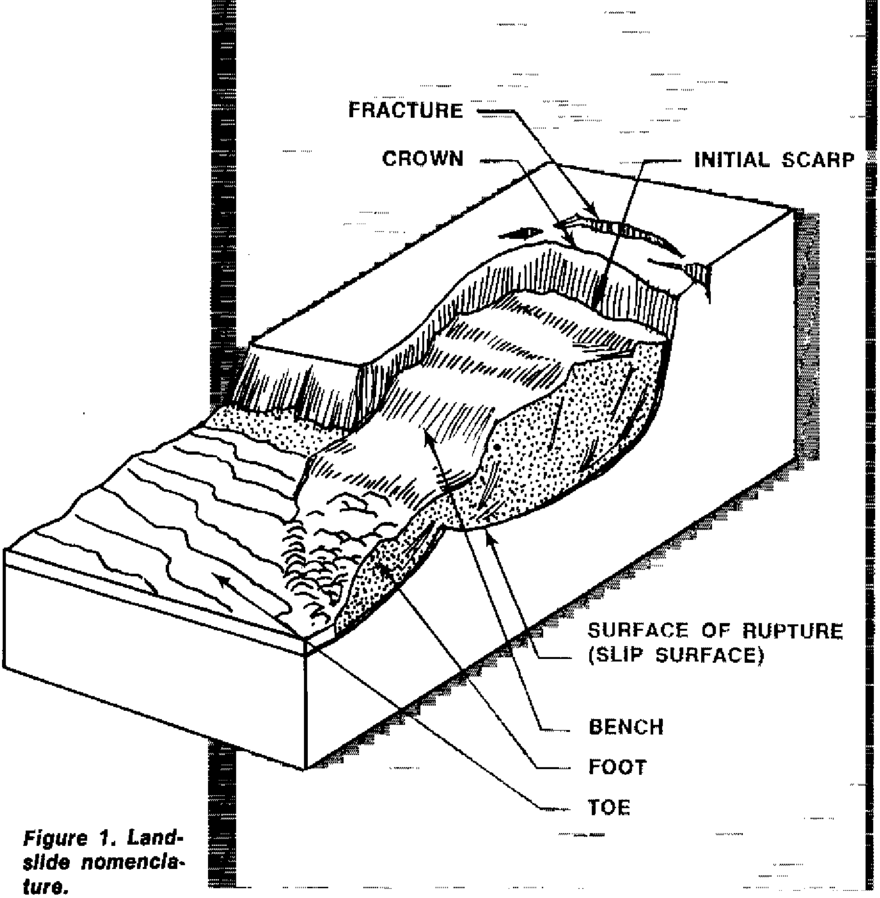


Figure 1. Landslide nomenclature.

Landslide Characteristics

Landslides take a variety of forms, but in almost all cases, a landslide can be defined as a rapid displacement of rock, soil, and sediments adjoining sloping ground in which the center of gravity of the mass of material advances downward and outward.

Each landslide has its own characteristics. The mechanisms, materials, and boundary restrictions may be quite different from slide to slide. However, slide nomenclature has been more or less standardized and is summarized in Figure 1.

For coastal landslides the toe usually is in direct contact with the ocean. When a slide reaches the ocean, waves immediately begin to act on the toe, removing the finer material and leaving larger boulders and cobbles to outline roughly the original toe. Where slide toes are composed of smaller fragments, wave activity may carry away most of the toe material. This produces a wave-cut cliff in what was formerly the bottom or foot of the slide. The cliff is often backed by a gently sloping bench; the surface upon which the slide moved is located beneath this bench.

Landslides occur where shearing stresses within materials exceed shearing resistance. It is the failure of material under gravity-induced shear stress that permits materials to slide down the slope. The actual mechanism of slide development has been described by geologist H. G. Schlicker this way:

> "*External* causes of landslides are due to the undercutting of the toe of a slope (oversteepening), addition of weight from embankment material or waste deposited along the upper edge of the slope, and from added weight of increased moisture content. Earthquakes or vibrations can be a cause and there is no doubt that vibrations from any source may 'trigger' a slide.
>
> "*Internal* causes of landslides are due to water in the ground. The ground-water produces both immediate and progressive decrease in shear strength of the soil. Immediate decrease of shear strength is generally caused by increase in pressure from water in the voids. This pressure is analogous to the forces exerted by a hydrostatic* head. Seepage pressure is a force exerted by ground-water flow due to the viscosity of water moving through minute passages in the soil. Continued seepage through slopes expels the air and apparent cohesion between the soil particles is eliminated, further weakening the soil. Although this mainly concerns conditions of rapid drawdown in reservoirs and stream channels, it is also true of

* *Refers to the height of a column of water under a given unit of pressure.*

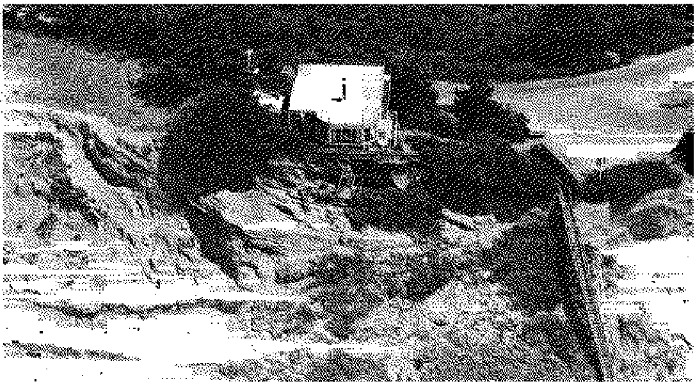
saturated soils below the water table.† Progressive decrease in shear strength results from removal of the soil binder and chemical decomposition of the mineral grains by ground-water action.

"As the shearing forces approach the shear strength of a soil mass, certain sections fail by rearrangement of the soil grains and the formation of hairline cracks. Excess water in the disturbed soil is forced into other sections of the soil and failure of the soil mass continues as if by chain reaction. When the shear strength along a possible slide plane is reduced sufficiently, the entire mass becomes mobile and a slide occurs. At the moment a slide begins, the shearing forces are but slightly greater than the shear strength of the soil, but sliding causes a reduction in strength of 20 to 90 percent, depending on the sensitivity of the soil. Movement of the slide rapidly increases as the soil loses its strength. As the slide progresses, the driving force is reduced through reduction in slope and mixing of the slide material with more stable foreign soil. When the resisting force again is equal to the shearing force of the soil the movement passes from sliding into slow creep. The surface of an old slide is particularly susceptible to the effects of excessive rainfall, since numerous deep fissures provide easy entrance for water and drainage is greatly disrupted."[9]

When a slide stops moving, equilibrium between gravity and the slide material's shearing resistance is established. Removal of the toe may upset the equilibrium by unloading the base, thus permitting repeated movement of the slide.

One simple method of classifying landslides is by the nature of the slip surface on which the slide occurs, as shown in Table 1. Places where landslides in each of these classifications occur are shown on the fold-out map in the center of this booklet.

† The upper limit of a portion of ground wholly saturated with water.



Figures 2 and 3. Beachfront homes perch precariously above landslide areas. Retreat of cliffs becomes obvious from the air.

Table 1.
Basic Landslide Types

Landslide type*	Nature of slip surface
Slump	Concave
Slide	Planar
Fall	Indeterminate—movement essentially vertical
Shift	Indeterminate—movement indeterminate

** The type of material moved can be used as a modifier. For example, movement of rock and terrace material along a concave slip surface would be termed "rock-terrace slump." If materials are considerably mixed, the word "debris" is applied to the landslide type.*


Figure 4. Rock and debris slump.


Figure 5. Block and rubble slide.

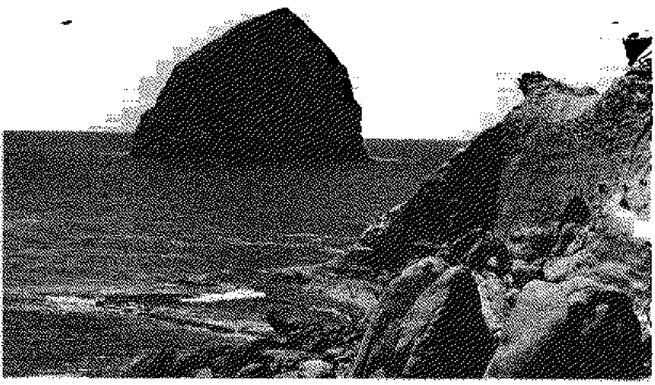


Figure 6. Rock fall.


Figure 7. Debris shift.

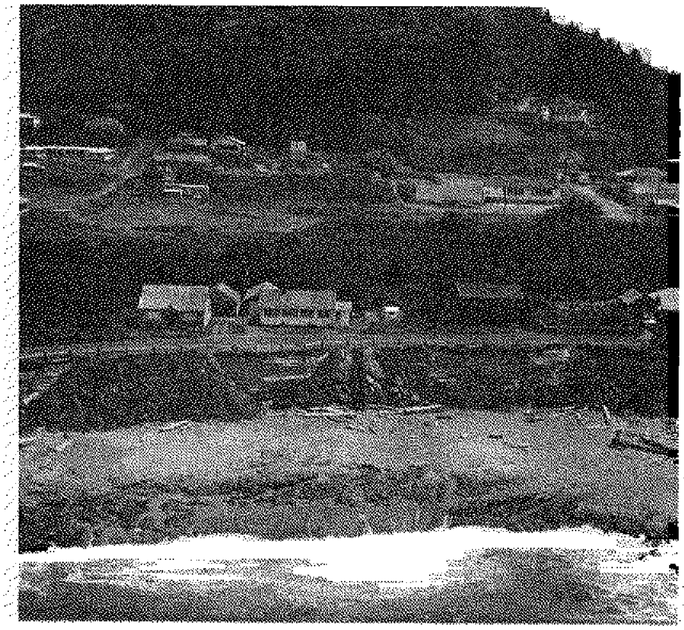


Figure 8. Road crews have dumped fill dirt and rock in an attempt to minimize slide activity near roadway.

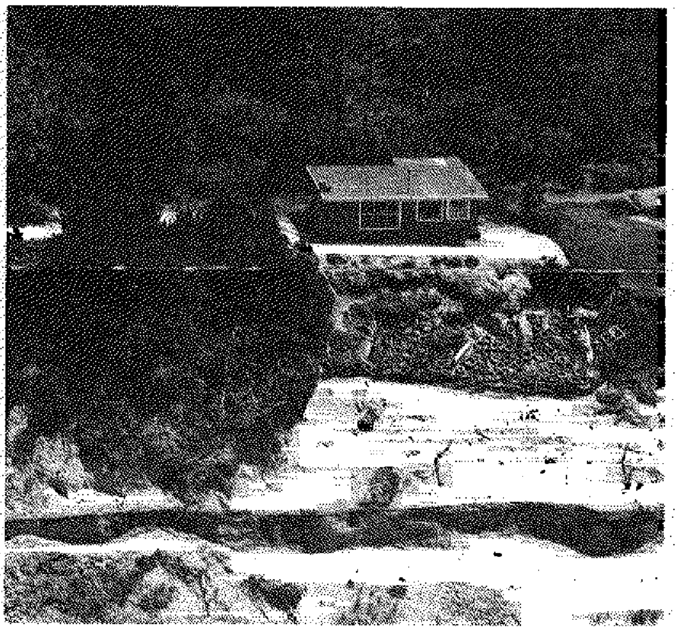


Figure 9. A unique method of slide prevention. A home owner has used old tires as riprap.

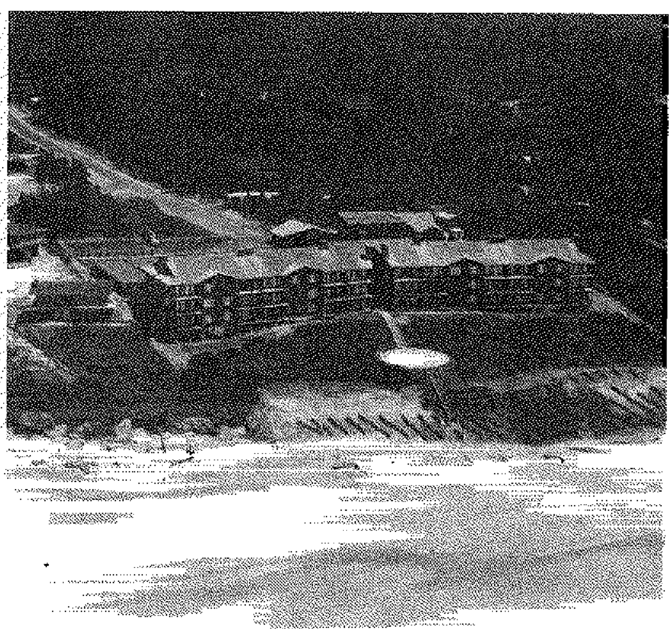


Figure 10. A coast resort motel has installed fencing and plantings to minimize slides in a slump area.

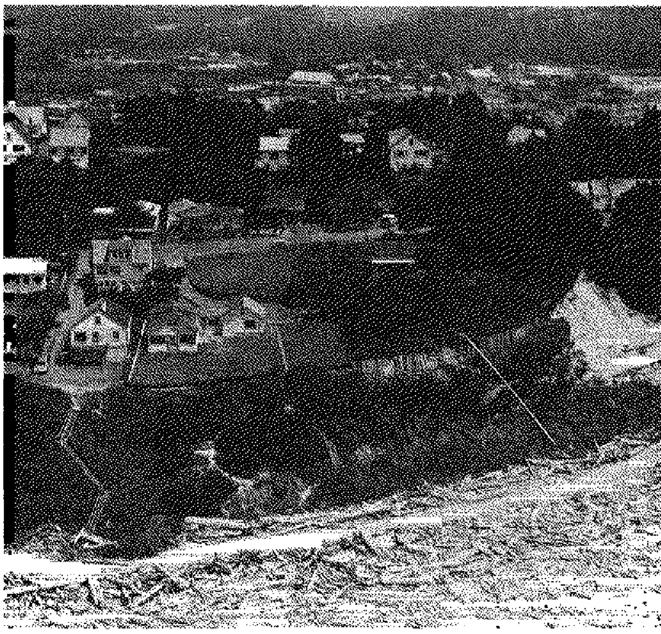


Figure 11. Dense foliage (left) and planking are two effective and inexpensive means of landslide prevention.

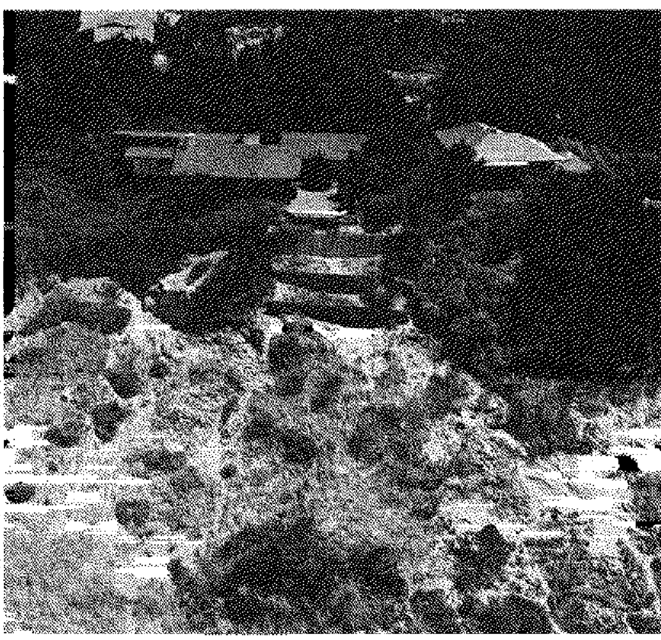
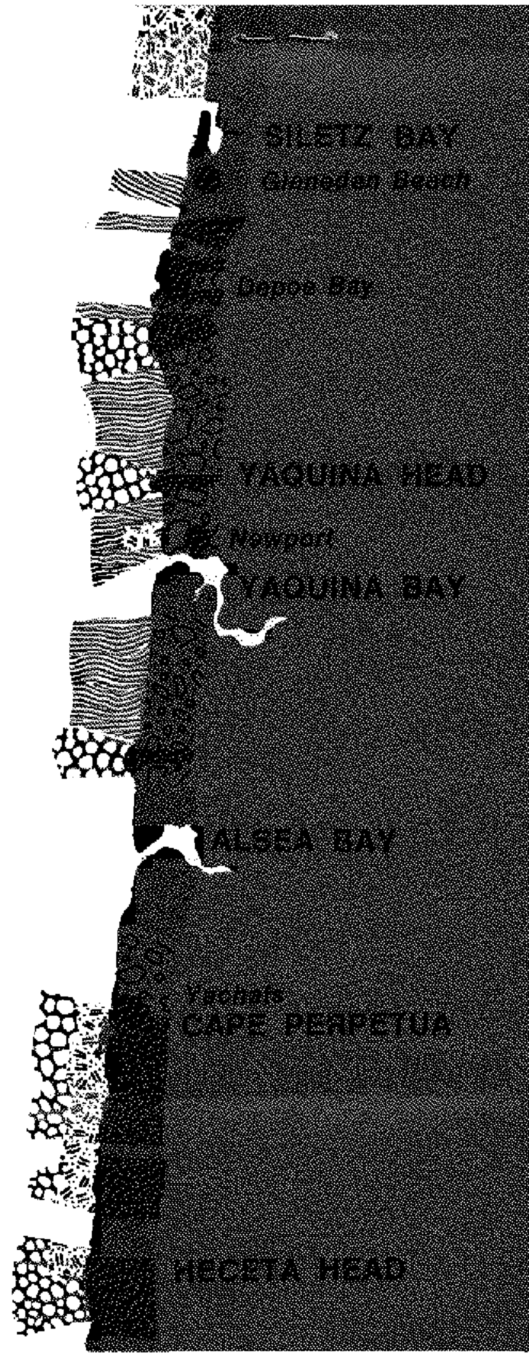
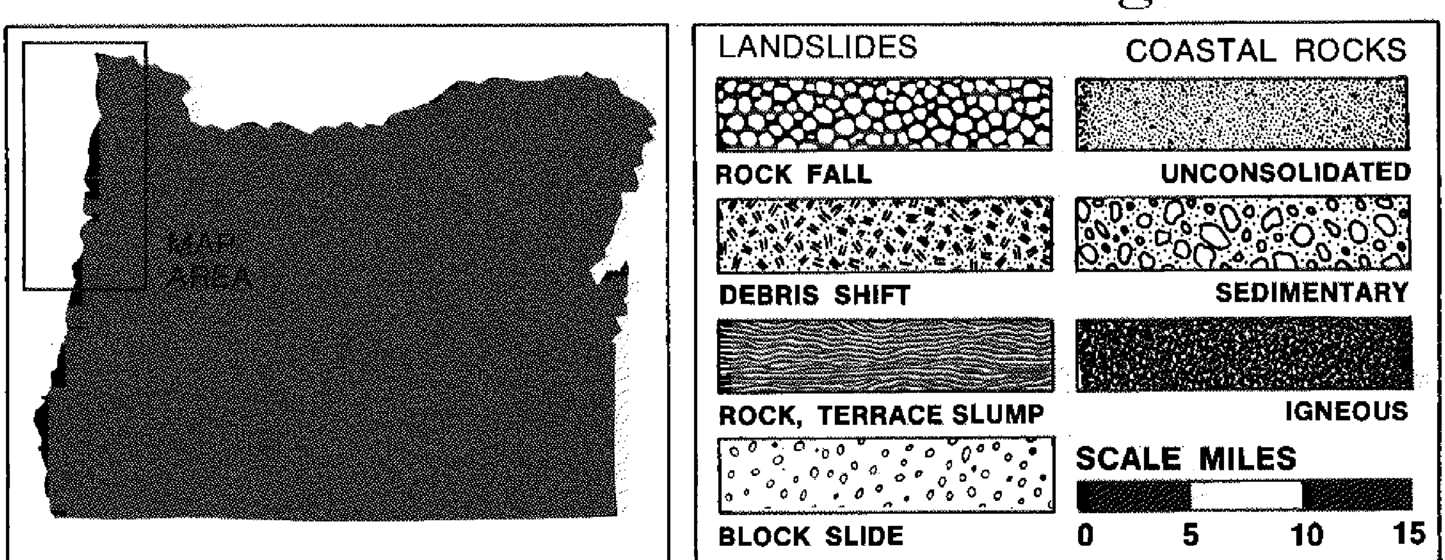


Figure 12. Tiered fencing has successfully deterred serious landsliding near this cliff-side beach house.



Landslide Distribution along the Northern Oregon Coast



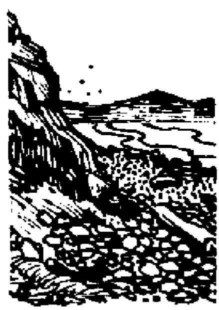
Landslides pictured on the foldout map (under pages 8 and 9) occur along the portion indicated by the pattern plotted in the offshore position. Slides are unlikely, although in some cases possible, along portions of the coast which show no pattern. Rock types exposed along the coast are shown along the landward side of the coast on the map.

No attempt has been made to show the distribution of terrace deposits.* For more detailed reports concerning the landslides shown on this map, you may wish to read "Coastal Landslides of Northern Oregon" by William B. North and John V. Byrne. It was published in the *Ore Bin*, Vol. 27, No. 11, in November 1965, and is obtainable from the Oregon State Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201.

** Unconsolidated sands and gravel overlying solid rock.*

Summary of Landslide and Rock Types

Landslides on the Oregon coast occur as the four basic kinds: slump, slide, fall, and shift. Each kind is usually associated with a definite coastal rock type. Igneous headlands and the headland material overlying igneous rocks are most susceptible to falls, either rock or debris. The resistant igneous rock is massive, providing few, if any, sloping zones of weakness such as bedding planes upon which slides can develop. Undercutting is slow and, when rocks break off, they fall in tabular masses leaving vertical cliffs. Joints and faults (two types of cracks), control the erosion of the igneous headlands. These cracks or fractures are zones of weakness that are eroded by waves. Evidence for weakening along nearly vertical fractures is seen in each headland. This weakening is particularly prominent on the western side of Tillamook Head and along Cape Perpetua.



Sedimentary rocks are involved in each type of landslide. Deep weathering of the sediments weakens the rock and makes the cliffs susceptible to undercutting by waves. Unloading of the cliff base disrupts equilibrium of the relatively coherent rock mass and slumping occurs. Block slides or "glides" are unusual in the sedimentary sequence, because beds are usually too thin for a separate block to detach and slide. Where sandstone has resisted deep weathering, some slides of tabular bodies on bedding planes have occurred, as on Cape Falcon.

Unconsolidated sands, silts, and gravels of uplifted marine terrace and dune deposits usually have no specific plane of movement and move as debris shifts. Mineral and rocky grains, acting as individual particles, provide no firm plane for movement of one mass over another. Slip-face sand movement, resulting in a cone or small fan, is common on dune and terrace faces. However, more often the oversteepened terrace cliffs move as debris shifts.

Landslide Frequency and Rate of Coastal Retreat

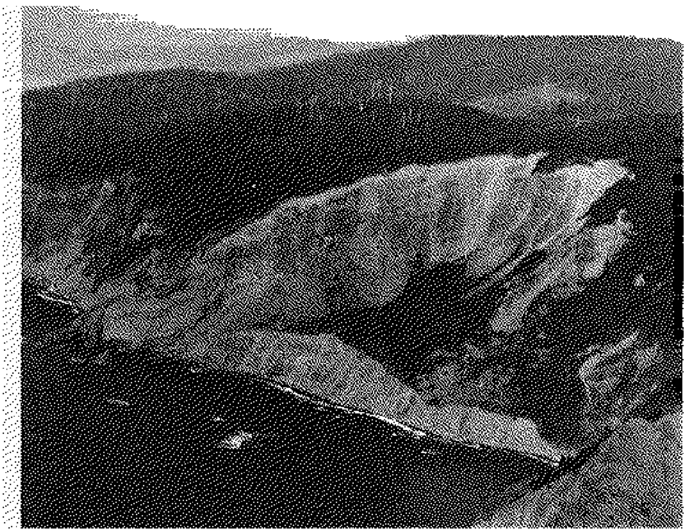
The occurrence of landslides can be correlated with high winter waves and increased rainfall. Studies by the Department of Oceanography at Oregon State University have shown that during the period from 1916 to 1949 most landslides occurred from late fall to early spring. The highest frequency of slides is during December and January, the period of major storms.

Losses due to landslides have been extensive in some regions. Ecola Park, just north of Cannon Beach, and Cascade Head, north of Lincoln City, have undergone considerable alteration. Landsliding has destroyed or disrupted more than 200 acres of land in four separate slides. In 1961, the Ecola Park landslide moved about 125 acres during a two-week period. On Cascade Head, a slide in 1934 carried 20 acres of pasture down toward the sea (Figure 13). Two other landslides on Cascade Head have each destroyed more than 14 acres of grazing land.

Severe damage to buildings, roads, and public utilities has occurred in numerous places along the northern coast—notably at Cape Meares near Tillamook and at Newport.

Coastline erosion in the vicinity of Cape Meares has been affected by jetty construction on the north side of the entrance to Tillamook Bay. This jetty apparently upset the equilibrium of sand transport by waves along the coast, causing a starvation of sand in the area south of the jetty. This has resulted in erosion of the entire sand and gravel spit, including the Cape Meares village area. Numerous estimates of erosion, based on town plat maps, aerial photographs, and direct observation have been made with regard to the rate of coastal retreat. From 1939 to 1961, the southern portion of Bay Ocean Beach was estimated to have retreated 500 feet. Closer to Cape Meares, materials are somewhat more resistant and the coast retreated 320 feet during the same period. During the winter of 1960 and 1961, 75 feet was eroded from the end of a street oriented at a right angle to the coastline in the village of Cape Meares. On the basis of several estimates, the average yearly coastal retreat has been about 30 feet in the vicinity of the village of Cape Meares.

Figure 13. Rock-terrace slump which has destroyed 20 acres of land on Cascade Head.



In Newport, coastal retreat has been equally serious. Town plats of 1902 and 1912 were used to indicate former position of the sea cliff. Between 1902 and 1964, the coastline retreated from 35 to as much as 490 feet in the northern portion of the city. In the southern part of the city, between 1912 and 1964, the cliff edge retreated from 40 to 220 feet. In parts of Newport, the coast has retreated as much as eight feet annually.

Landslide Prevention

Total prevention of coastal landslides is an expensive undertaking. Such procedures as rock bolting, construction of complicated drainage systems, retaining walls and sea walls, and buttressing are well beyond the means of the average property owner. However, where limited steps have been taken to retard small but economically damaging slides, the results appear to be well worth the effort.

In the Oceanlake area of Lincoln City and near Seal Rock, north of Waldport, attempts are now being made to control the undercutting of the terrace material. Basalt boulders or riprap, piled at the base of the cliffs serve to weight the cliff base and prevent outward movement (Figure 14). Riprap also lessens the wave impact on the cliff base by providing a leading edge of resistant material to absorb much of the wave energy.

On U. S. Highway 101 at Boiler Bay, north of Depoe Bay, a successful attempt has been made to prevent waves from undercutting the highway on the east edge of the bay (Figure 15). The entire geological formation at Boiler Bay and the sand slope beneath the highway has been covered by riprap. This inexpensive measure has retarded cliff recession and probably has saved a section of the highway.

Grass and low brush planted on slopes hold sand

Figure 14. Boulders (left) and stacked pilings weight the cliff base and prevent land loss from sliding.

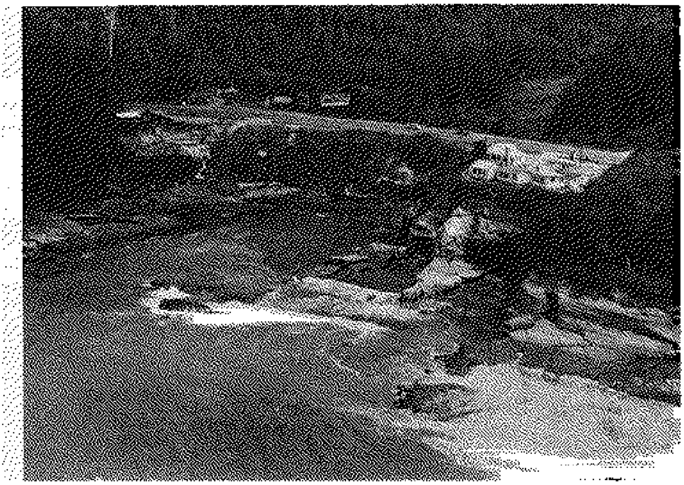


Figure 15. Riprap at Boiler Bay helps to slow down landsliding and to protect U.S. Highway 101.

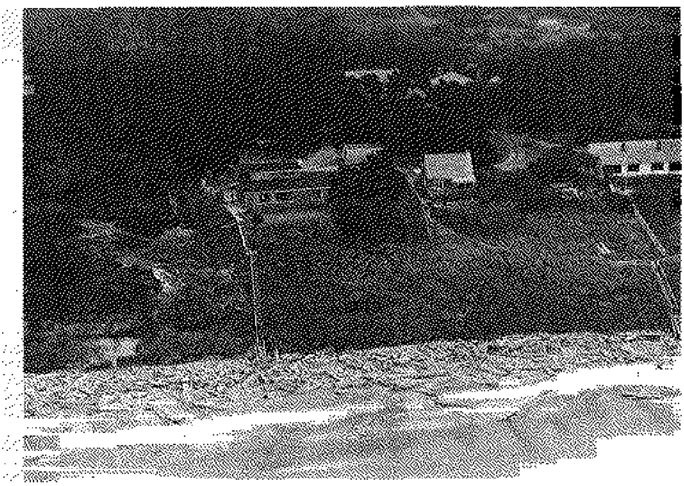


Figure 16. Property owners with grass and shrub plantings on coastal banks have had little trouble with slides.

Here is a list of papers and articles for readers who wish to learn more about landslides:

1. ALLEN, JOHN ELIOT and LOWRY, WALLACE D., 1944, "An investigation of the sea-cliff subsidence of March 30, 1943 at Newport, Oregon" (abs.) *Oregon Academy of Science Proc.* 1.31 (1943-1947).

2. BYRNE, JOHN V., 1963, "Coastal erosion, northern Oregon." In *Essays in Marine Geology in Honor of K. O. Emery.* Los Angeles, Univ. Southern California Press, p. 11-33.

3. ——————, 1964, "An erosional classification for the northern Oregon coast." *Assn. American Geographers Annuals* 54, p. 329-335.

4. DICKEN, SAMUEL N., 1961, *Some recent physical changes of the Oregon coast.* Eugene, Oregon, Univ. of Oregon Dept. of Geography, 151 p.

5. ECKEL, EDWIN B. (ed.), 1958, *Landslides and engineering practice.* Washington, D. C., Highway Research Board (Nat. Acad. Sci. National Research Council Pub. 544, Highway Research Board Spec. Rept. 29, 233 p.)

6. LADD, GEORGE EDGAR, 1935, "Landslides, subsidence, and rock falls." *American Rwy. Eng. Assn. Bull.* 37(377), p. 1-72.

7. NORTH, WILLIAM B., 1964, *Coastal landslides in northern Oregon.* Oregon State Univ., Dept. of Oceanography master's thesis, 85 p.

8. NORTH, WILLIAM B. and BYRNE, JOHN V., 1965, "Coastal landslides of northern Oregon." *The Ore Bin,* vol. 27, no. 11, p. 217-241.

9. SCHLICKER, H. G. 1956, "Landslides." *The Ore Bin,* vol. 18, no. 5, p. 39-43.

10. SCHLICKER, H. G., CORCORAN, R. E., and BOWEN, R. G., 1961, "Geology of the Ecola State Park landslide area, Oregon." *The Ore Bin,* vol. 23, no. 9, p. 85-90.

11. SHARPE, C. F., STEWART, 1938, *Landslides and related phenomena.* New York City, Columbia Univ. Press, 137 p.

12. TERZAGHI, KARL, 1950, "Mechanisms of landslides." In *Application of Geology to Eng. Practice,* Berkey Vol. Geol. Soc. America, p. 83-123.

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